Impact of Redd Loss at Vernita Bar on Hanford Reach Chinook Salmon Production

U.S. Department of Energy
Bonneville Power Administration
Division of Fish & Wildlife

Fisheries Research Institute
School of Fisheries

October 1988

SH
173.5
.R63
1988

Final
Report
1988

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

For copies of this report, write to:

Bonneville Power Administration
Division of Fish and Wildlife - PJ
P.O. Box 3621
Portland, OR 97208

¶ ILL MOD SID: 07185 IL

NO@ will ship.

ILL Pending 20000128 Record 1 of 6

▸ :ILL: 6586228 :Borrower: OLP :ReqDate: 20000125 :NeedBefore: 20000224

:Status: SHIPPED :RecDate: :RenewalReq:

:OCLC: 36464226 :Source: OCLCILL :DueDate: 20000227 :NewDueDate:

:Lender: *NO@,NO@,NO@ ¶

▸ :CALLNO: ¶

▸ :AUTHOR: Rogers, Donald E. ¶

▸ :TITLE: Impact of redd loss at Vernita Bar on Hanford Reach chinook salmon production : final report / ¶

▸ :EDITION: any ¶

▸ :IMPRINT: Portland, OR : U.S. Dept. of Energy, Bonneville Power Administration, Division of Fish and Wildlife ; Seattle, WA : Fisheries Research Institute, School of Fisheries, University of Washington, [1988] ¶

▸ :VERIFIED: OCLC ¶

▸ :PATRON: Pressman, Peter ¶

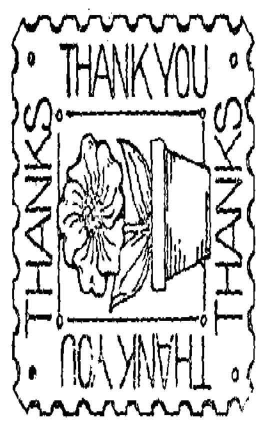
▸ :SHIP TO: Interlibrary Loans/Aubrey R. Watzek Library/Lewis & Clark College/ 0615 SW Palatine Hill Road/Portland, OR 97219-7899 ARIEL IP: 149.175.20.3 ¶

▸ :BILL TO: Above [¶

▸ :SHIP VIA: Courier/Library Rate :MAXCOST: $20.00IFM

:COPYRT COMPLIANCE: ¶

PLEASE LEAVE SLIPS IN BOOK


THANK YOU
THANKS
THANKS
THANK YOU

IMPACT OF REDD LOSS AT VERNITA BAR ON HANFORD REACH CHINOOK SALMON PRODUCTION

FINAL REPORT 1988

Prepared by

D.E. Rogers and R. Hilborn
Fisheries Research Institute
School of Fisheries
University of Washington
Seattle, WA 98195

Property of CSC Library

Prepared for

Robyn MacKay, Project Manager
U.S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208
Project No. 87-413
Contract No. DE-AM79-87BP35885

October 1988

FEB 2 6 1997

U.S. DEPARTMENT OF COMMERCE NOAA
COASTAL SERVICES CENTER
2234 SOUTH HOBSON AVENUE
CHARLESTON, SC 29405-2413

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

In this report, we examine the effect on chinook salmon production within the Hanford Reach of redd loss at Vernita Bar. The current target escapement of 40,000 chinook past McNary dam has no real biological justification because the wrong data were used in the analysis and the methods used are now known to be very unreliable for the type of data available. The escapement that maximizes MSY may be lower than 40,000, or much higher, and reliable estimates of optimum escapement are unlikely to be available for several more years.

If the optimum escapement is truly 40,000 (or less), then loss of a few hundred redds on Vernita Bar would have no detrimental, and possibly beneficial consequences on total chinook production from the Hanford Reach, so long as escapements are in excess of 40,000. If the optimal escapement is actually much higher (60,000+), the biological cost of redd loss when escapements are in excess of 40,000 would be about two fish in the adult return for every redd lost. So long as escapements exceed 40,000, the issue of redd loss at Vernita Bar is simply a question of losing a few dozen or hundred adult fish in the next brood and is not an issue of stock conservation.

IMPACT OF REDD LOSS AT VERNITA BAR ON HANFORD REACH CHINOOK SALMON PRODUCTION

Introduction

The last major naturally spawning stock of chinook salmon in the Columbia River is located in the Hanford Reach between Priest Rapids and McNary dams. This race of fall chinook salmon (also called "upriver brights") spawns throughout the 90 km of the reach; however, one spawning area of about 6 km, Vernita Bar, has special management significance.

In April 1976, low discharges from Priest Rapids Dam over a period of 32 hours caused heavy mortalities of emergent fry on Vernita Bar. This prompted regulations on minimum discharges from Priest Rapids dam to protect all but a very few redds on the bar and a study of the effect of flow on redd distribution during 1978-1983. The study showed that management of discharges during the fall spawning period could ease the subsequent minimum flow requirements for incubation and emergence (Chapman et al 1986). Nevertheless, there remained a conflict between power needs and fish needs that was largely resolved in favor of fish needs partly because spawner abundance was at or below that desired by fisheries management. In 1987, the number of spawners in the Hanford Reach was about three times greater than the "goal" and this raised the question of whether the same flow requirements for redd protection on Vernita Bar were necessary or even desirable.

The purpose of this report is to assess the impact of flow regulation at Priest Rapids dam on production of chinook salmon in the Hanford Reach of the Columbia River. This analysis is based upon data available at the time of the work (Nov. 87-Mar. 88), does not involve any new data collection, and is intended primarily as an assessment of the current state of knowledge of the problem by independent university researchers.

Given the data available, it is not possible to quantitatively assess the impact of Priest Rapids release patterns on chinook production. There are numerous possible hypotheses about the relationship between habitat availability, spawning stock size, flows and survival; and the existing data do not allow us to determine which of these hypotheses are correct. What we will do is examine the status of the stocks and then discuss the alternative hypotheses, the extent to which the data are consistent with the hypothesis, and the impacts of flow variation on chinook production if the hypothesis was true. The alternative hypotheses can be divided into two basic groups; those built around an underlying stock recruitment model, and those described as habitat based production relationships.

Data Sources

Very little of the statistics on the Hanford Reach chinook salmon stocks is published in the literature; instead, is is available mainly in project reports or in agency files. We relied on Mr. Mike Dell (Grant County P.U.D.) for recent (through 1987) escapement estimates (dam counts), aerial survey counts and juvenile releases. Escapement and return statistics (in-river catch plus escapement by age class) were available from the Washington Department of Fisheries for only upriver brights combined, i.e. all fish above McNary. Estimates of annual runs since 1971 for major stock complexes in the Columbia River and some other Pacific coast areas were obtained from the Pacific Fishery Management Council (Review of 1987 Ocean Salmon Fisheries, Feb 1988). Earlier historical run statistics for the Columbia River are available in Korn (1977).

To provide some perspective on the fluctuations in abundance of Columbia River chinook salmon, we utilized escapement and return data for the Nushagak River stocks presented in Nelson (1987) and trends in historical salmon catches from the North Pacific as reported in Fredin (1980), International North Pacific Fisheries Commission (INPFC) Secretariat (1979), annual INPFC Statistical Bulletins, and INPFC as well as other agencies for 1985-1987 preliminary statistics.

Status of the Stocks

Commercial fisheries on North American salmon developed in the late 1800s and early 1900s. By about 1920, most of the major stocks were under extensive exploitation and there followed a thirty-year period of sustained production and then a decline in the early 1950s. Relatively low production continued through the mid-1970s, but since then salmon production has equalled or exceeded earlier historical production (Rogers 1987 and Tables 1-5). Columbia River fall chinook salmon (presumably including the Hanford Reach) had undergone similar changes in abundance through the early 1970s (Korn 1977); although for chinook salmon stocks combined (California to southeastern Alaska), the catches from the 1920s to 1970s were rather stable as declines in natural stocks were replaced by hatchery production (Rogers and Salo 1985).

Catches of chinook salmon from California to southeastern Alaska (southern region) declined in the 1980s in sharp contrast to catches of the other species and especially catches in the northern region, i.e. upper Gulf of Alaska and Bering Sea coast or central and western Alaska (Fig. 1). Since the decline in the early 1980s there has been a modest increase in chinook production coastwide and an exceptional increase in the abundance of Columbia River fall chinook salmon (inriver) relative to the other major chinook salmon stocks (Fig. 2 and Tables 6-7). However, it is difficult to interpret changes in the inriver runs because a significant proportion of Columbia River chinook salmon are caught in ocean fisheries mixed with stocks from other rivers. Perhaps the inriver runs increased partly because ocean catches of Columbia fall chinook salmon decreased.

The upriver fall chinook salmon of the Columbia (all those originating above McNary) have undergone some recent changes in abundance that are similar to the changes observed in the Nushagak River stock of Bristol Bay, Alaska from 1966 through 1983. Both stocks experienced large increases in returns with relatively little change in escapement (Fig. 3 and Table 8). In the Nushagak case, the larger returns from the 1975-1977 broods encouraged management to increase escapements (1978-1983). This apparently was a mistake, since the larger escapements (more than double the prior goal) have been very poor producers. The McNary escapements since 1985 have also been more than double the management goal and may likewise produce poorly if the goal of 40,000 adults (ages 3 and older) was approximately correct. Unfortunately, past and future escapements may have little measurable impact on future runs because the upriver fall chinook are not managed as a natural stock.

Attempts to artificially enhance the production of chinook salmon in the Hanford Reach have gone on for over 20 years—first as a spawning channel that apparently failed and now as a hatchery that is apparently succeeding. The recent large inriver returns and the relative production (return per escapement) of upriver fall chinook salmon are highly correlated with the number of hatchery smolts released (Fig. 4 and Table 9). In addition to the trend of increasing hatchery releases there has been an increase in the collection and transportation of smolts past McNary, and this is also correlated with recent returns and relative production. These apparently successful enhancement techniques for upriver fall chinook salmon may not be so successful for the natural spawners in the Hanford Reach and, at the very least, make it very difficult to evaluate the impact of flow regimes on natural production from the Hanford Reach or Vernita Bar.

The escapements of chinook salmon to the Hanford Reach (natural spawners) are estimated by counts at McNary minus counts at Priest Rapids, Ice Harbor and volunteers--hatchery or spawning channel (Table 10). Jacks (precocious adults, age 2) are counted separately from older adults based on length; otherwise, age compositions were not available. After 1971, when Priest Rapids counts declined, the Hanford Reach received an average of 75% of the older adults and 80% of the jacks counted past McNary (Fig. 5A). The differences in adult and jack counts may be caused by different length criteria at the dams and hatchery rather than a real difference in age composition. Most noteworthy was the relatively low percentage of adults (62%) in the Hanford Reach in 1987 which was caused by a greater increase in the Priest Rapids and hatchery counts than in the natural spawners in the Reach.

The distribution of spawners within the Hanford Reach can be examined with the aerially surveyed redd counts by Watson (1970). The redd counts on Vernita Bar ranged from 32% to 42% of all redds counted in the Hanford Reach with two exceptions (Fig. 5B and Table 11). Aerial surveys can detect redds only in relatively shallow water (about 3m) and most spawning probably occurs in deeper water (M. Dell, personal communication). Mr. Watson changed survey methods in 1981 (counted only at low water) and thus counts increased relative to the number of spawners present.

After 1981, when escapements were at a low point, there were successive increases in adult counts past McNary, from 21,000 to 157,000. There were also successive increases in the redd counts on Vernita Bar, but these increases were small relative to increased counts in other areas of Hanford Reach (Fig. 5D-C) and small relative to the increase in escapement past McNary. Escapements increased seven-fold between 1981 and 1987, whereas Vernita Bar redd counts only increased 52%. Thus, the importance of Vernita Bar as a spawning location appears to decline as the escapement has increased.

Stock and Recruitment

The tradition in consideration of Hanford Reach chinook has been stock recruitment analysis. The current 40,000 (age 3+) escapement goal past McNary was derived from such an analysis in 1982, and our understanding is that efforts are now underway to update the data base and reevaluate the escapement goal. The 40,000 escapement goal now in place was derived in a document by the Technical Advisory Committee, dated July 1982. It was recognized in their report that the estimate of 40,000 was "tenuous". Nevertheless, the 40,000 number has become an important figure in both the Columbia, and chinook management of the entire Pacific Coast.

Given our current understanding of the power of stock recruitment analysis, we can now say with hindsight that there is little if any biological justification for this number. The following specific points need to be considered:

1. The data used in the analysis did not consider ocean catches.
2. At the time of the analysis, few scientists were aware of the serious biases in stock recruitment data that result from imperfect spawning escapement data (Walters and Ludwig, 1982). The imprecision of the estimates of how many fish actually spawned in the Hanford reach (as opposed to how many passed McNary dam), and the very narrow range of spawning escapements represented in the data, preclude a reliable estimate of the optimum spawning stock. It may easily be anywhere above 20,000, it could be several hundred thousand, or it could be 40,000. The data available in 1982 were insufficient to make any determination of the expected production of spawning stocks from 40,000 and up.
3. Even in the absence of inaccuracy in spawning escapements, stock recruitment analysis of time series data will usually be biased towards a too low estimate of optimum escapement (Hilborn and Starr, 1984; Walters, 1985). Again this problem was not known in 1982, but we now know to be doubly distrustful of stock recruitment analysis from data with a very narrow range of spawning stock sizes.
4. Although the exact method used to fit the models is not described in the 1982 document, it is almost certain that they did not consider the effect of stochasticity on the optimum escapement. Hilborn (1985) showed that the optimum escapement is always higher than that predicted by the simple fit of the Ricker model. This is not a major effect, but underlines the fact that while the Ricker model may have been fit to the data in 1982, there was little understanding of the statistical basis of estimating optimal escapement from such data.

In River Return—1962-1983 Broods

Data are now available on spawning stock through 1987 and the returns from the 1983 brood (4 year olds). Using the McNary dam counts of adults (age 3+) as the estimated spawning stock, we obtain the stock recruitment graph shown on the left side of Figure 6. Note that this still does not include any ocean fishing mortality.

If we fit the Ricker stock recruitment curve, we obtain optimal escapement of approximately 34,000 fish. More importantly the stock recruitment curve is extremely flat over the observed range of spawning stock sizes. All the problems mentioned in the previous discussion of the 1982 estimate are valid for this analysis. There simply has not been enough variation in spawning stock to understand the underlying relationship. However, if one were to believe this analysis, it would suggest that increases in escapement over 40,000 actually reduce total production, and therefore any mortality on redds caused by flow variation at Priest Rapids dam, would likely be beneficial to total production. These data suggest that between 30 and 60 thousand adults,there is some density dependent mechanism that limits total productivity, and additional spawners, or additional redds will not increase total production. In fact, beyond the 60,000 escapement, the total production decreases significantly, and the large spawning stocks of 1985-1987 would be expected to have very poor returns.

Anyone who believes in the stock recruitment analysis would therefore accuse the management agencies of serious mismanagement during the 1985-1987 period, and any mortality of spawners or redds would have been thought to be beneficial! There would be absolutely no concern about redds being killed on Vernita bar when escapements were over 40,000.

Adjusting for Ocean Fishing Mortality

One of the major failings of the 1982 stock recruitment analysis was that it did not consider the ocean catch as part of the production. While from a very narrow up-river Columbia perspective, all fishing mortality outside of the river may be considered as "natural" mortality, if we really want to maximize the benefits from the Hanford Reach we should include estimated ocean catch as part of the recruitment.

We have made a very preliminary attempt to do this using the estimated ocean fishing mortality on the 1975 to 1983 broods of Priest Rapids Hatchery fall chinook from an analysis performed by the International Pacific Salmon Commission (IPSC), chinook technical committee. Table 12 shows the data used. We have included an estimate of the 1983 brood year return, since this is the single most informative spawning stock size in the data sequence, and it is clear, despite the fact that the age 5 returns are not yet available that the brood year production was very good.

These data show increasing recruits per spawner with larger spawner stock sizes, and therefore the Ricker curve gets steeper with increasing stock sizes (right side of Figure 6). The estimated optimal escapement is therefore infinite! This is, of course unbelievable, however it does suggest the the optimal stock size (for MSY) may be considerably greater than 40,000.

Utility of Stock Recruitment Data for Hanford Reach Chinook

Until the brood year returns are available for the large spawning stocks of 1985-1987, there is little to be learned from the analysis of stock recruitment data for this population. A pressing need is for a better data base: there appears to be no consensus on what numbers to use as Hanford Reach spawners or exactly what to include as brood year returns. It is possible that if a better, carefully constructed data base was available, a stock recruitment pattern would appear from the 1962-1983 data, but certainly the important data will be those that come from the broods of the large spawning stocks now at sea.

Unfortunately, the interpretation of the next few data points will always be ambiguous. If the returns are large, then statistical fits will suggest that much larger spawning stocks are desirable; if returns are poor then the optimum escapement would appear to be in the 30,000 to 40,000 range. It is also quite possible that some of the returns will be large and some small. Someone will always be able to argue that the good returns (if they are good), or the poor returns (if they are poor) were caused by oceanic conditions and not representative of the "average" stock recruitment relationship. The only hope for a truly unambiguous answer is 5 or more data points roughly grouped together. Experience with salmon spawner recruit data suggests this is not particularly likely.

Interpretation of the cost of redd mortality due to flow variation on Vernita Bar, will be quite a bit more straightforward. If the next few broods produce large returns, and the optimum escapement is raised to 60,000 or even 150,000, then the loss of dozens, or even hundreds of redds on Vernita Bar would be of no measurable or significant consequence to the Hanford stock, so long as escapements are 40,000 fish or more. If the next few broods produce small returns, then the optimum escapement will be assessed to be 40,000 or less, and loss of redds when escapements are over 40,000 would be of no significance (downward slope of recruitment curve).

Habitat Availability and Utilization

An alternative approach to understand the relationship between spawners and subsequent production is to explicitly consider the relationship between habitat available, spawner utilization, redd survival, fry production and downstream migration. The key components of such an analysis would include:

1. A description of habitat availability under different flow levels.
2. A description of how the spawners distribute themselves over the available habitat.
3. A method for calculating the survival rate of redds and juveniles under different flow regimes.

From the available documentation, it appears the parts 1 and 3 could be accomplished from existing information. Part 2 would require some assumptions about the preference of spawning females for different gravel sizes and flow regimes.

Much of the current controversy over Vernita Bar spawning is the increasing number of redds higher up on the Bar. It is generally accepted among salmon biologists that when spawning densities increase, some spawners are forced out of preferred habitat into marginal habitat. Marginal habitat is commonly thought of as either less desirable substrate or higher probability of redd loss at low water. Such use of marginal habitat is often cited as one of the mechanisms for the decreasing slope of the spawner recruit curve at higher spawning densities.

Therefore, it is to be expected that as the stock approaches and exceeds its optimum spawning stock, more redds should appear higher up on Vernita Bar, and almost certainly in less desirable habitats throughout the entire Hanford Reach. The value of the redds to chinook production is clearly much less than redds deposited lower down on Vernita Bar for two reasons:

1. Given that there are more spawners, each redd constitutes a small proportion of the total stocks productive potential.
2. Eggs deposited in marginal habitat have a lower expected survival rate than eggs deposited in prime or preferred habitat. (It should be noted that the redds higher up on Vernita Bar may be considered marginal to some extent because of the flow regime which is under human control, and given a very high release level may produce good survivals).

Impacts of Redd Loss

The biological question associated with alternative flow regimes in the Hanford Reach is what is the likely impact on chinook production of alternative outflows from Priest Rapids dam. It is accepted by all parties that sustained drops in flow level will dry and kill redds on Vernita Bar, and the number of redds killed depends on where spawning occurs, and the duration of redd drying.

When spawning stocks are above 40,000 (and most likely even below that level), we are not dealing with an issue of stock survival or long term conservation, we are simply dealing with the trade off of letting fish spawn now to produce more fish in the future. The biological definition of MSY is the level of spawning stock at which the stock can be expected to produce on average the maximum harvestable surplus. At this level, the last pair of spawning chinook (that is the 20,000th pair if 40,000 is the MSY optimum escapement), can be expected to produce exactly 2 adults in the return. Thus the value of adding, or losing a fish in the escapement is exactly what fish are worth in the catch (when the stock is at MSY escapement). If the spawning stock is greater than MSY escapement then the value of spawners (or redds) is actually less than the value in the catch.

The loss of 250 redds from a spawning stock of over 100,000 fish could not possibly produce measurable or significant effects on the resultant production and the economic cost of such loss would, at the maximum be the maximum recruits per spawner times the 500 spawners involved in the redds. If we accept that the spawning stock is at or above the optimum escapement for MSY, then the economic cost of such redd loss would be at most the value of the 500 spawners to the fishery.

Conclusions

There is great uncertainty about the relationship between the number of chinook spawning in the Hanford Reach and the resultant production of adults. The currently used optimum escapement number of 40,000 past McNary is based on the wrong type of data and analyzed without a due appreciation of the problems in stock recruitment analysis. The true optimum escapement for MSY may be below or possibly far above 40,000.

Concern about the impact of killing redds on Vernita Bar is certainly real. However, it must be recognized that when spawning stocks are anywhere near or above the optimum escapement, the impact of redd mortality is simply a reduction in the expected future production, and that this impact, even in the worst scenarios constitutes less than 1% of the total stock. If the stock is truly above the MSY escapement then it is possible that redd loss would actually benefit total production. The biological cost of redd loss when escapements are high (above 40,000) cannot be precisely determined, but will be approximately two fish (one male and one female) per redd lost.

In the process of reviewing the available information on the Hanford Reach chinook, it became quickly clear that the available data had not been assembled in a particularly useful fashion. The following data would have been highly desirable, and we were surprised that the agencies had not produced it.

1. An agreed upon set of data giving brood by brood Hanford Reach spawners, and inriver returns by age. We found several different sets of spawner and return data, with different measures used as indices of both spawners and returns.
2. Estimates of the ocean catch of Hanford Reach chinook. These data are essential for a proper stock recruitment analysis.
3. A table of the area available for chinook spawning within Hanford Reach under different flow levels, and how much of each area would be dried out under flow reductions. The data should be stratified by bottom type, and water depth, as well perhaps as cfs at the gravel surface.

We would suggest that the state, tribes and power agencies get together an agreed-upon data base prior to any discussion of optimal escapement, or regulation strategies.

References

Chapman, D.W., D.E. Weitcamp, T.L. Welch, M.B. Dell and T.H. Schadt. 1986. Effects of river flow on the distribution of chinook salmon redds. Transactions of the American Fisheries Society 115:537-547.

Fredin, R.A. 1980. Trends in North Pacific salmon fisheries. Pages 59-114 in W.J. McNeil and D.C. Himsworth, editors, Salmonid Ecosystems of the North Pacific. Oregon State University Press, Corvallis, OR.

Hilborn, R. 1985. Simplified calculation of optimum spawning stock size from Ricker's stock recruitment curve. Canadian Journal of Fisheries and Aquatic Sciences 11:1833-1834.

Hilborn, R. and P.Starr. 1984. Making stock recruitment analysis work. Pages 227-244 in P.E.K. Symons and M. Waldichuk, editors, Proceedings of the Workshop on Stream Indexing for Salmon Escapement Estimation, West Vancouver, B.C., 2-3 February 1984. Canadian Technical Report Fisheries and Aquatic Sciences.

INPFC Secretariat. 1979. Historical catch statistics for salmon of the North Pacific Ocean. International North Pacific Fisheries Commission Bull. 39. 166 p.

Korn, L. 1977. Information on Columbia River salmon runs and fisheries.International North Pacific Fisheries Commission Bull. 36:1-14.

Nelson, M.L. 1987. History and management of the Nushagak chinook salmon fishery. Alaska Dept. Fish and Game Bristol Bay Data Report 87-1. 137 p.

Rogers, D.E. 1987. Pacific salmon. Pages 461-476 in D.W. Hood and S.T. Zimmerman, editors, The Gulf of Alaska. U.S. Government Printing. Washington D.C.

Rogers, D.E. and E.O. Salo. 1985. Trends in natural and hatchery production of chinook salmon. NOAA Technical Report NMFS 27:39-43.

Walters, C.J. 1985. Bias in the estimation of functional relationships from time series data. Canadian Journal of Fisheries and Aquatic Sciences 42:147-149.

Walters, C.J. and D. Ludwig. 1982. Effects of measurement errors on the assessment of stock-recruitment relationships. Canadian Journal of Fisheries and Aquatic Sciences 38:704-710.

Watson, D. 1970. Fall chinook salmon spawning in the Columbia River near Hanford 1947-1969. Battelle Pacific Northwest Laboratories, BNWL-1515, UC-48, Richland, Washington.

Table 1. Annual commercial and sport catches of chinook salmon in millions of fish.

	North America						Asia	
	Calif.- Wash.		British Columbia		SE Alaska	C&W Alaska	Japan	USSR
Year	Comm.	Sport	Comm.	Sport	Comm.	Comm.	High seas	Coastal
means								
1921-50	1.9	--	0.6	--	0.5	0.2	<0.1	0.1
1951-70	1.4	0.4	1.0	0.1	0.3	0.2	0.2	0.1
1971	1.3	0.6	1.6	0.1	0.3	0.3	0.3	0.2
1972	1.3	0.6	1.6	0.2	0.3	0.2	0.4	0.2
1973	2.2	0.7	1.4	0.2	0.3	0.2	0.3	0.2
1974	1.5	0.7	1.5	0.3	0.3	0.2	0.5	0.2
1975	1.7	0.8	1.4	0.4	0.3	0.2	0.3	0.2
1976	1.6	0.6	1.5	0.5	0.2	0.3	0.5	0.2
1977	1.7	0.6	1.5	0.4	0.3	0.3	0.3	0.3
1978	1.3	0.5	1.4	0.5	0.4	0.4	0.3	0.3
1979	1.5	0.5	1.3	0.4	0.4	0.5	0.3	0.3
1980	1.4	0.4	1.2	0.4	0.3	0.4	0.9	0.1
1981	1.2	0.4	1.1	0.3	0.3	0.6	0.3	0.1
1982	1.6	0.4	1.2	0.2	0.3	0.6	0.3	0.1
1983	0.7	0.4	1.0	0.2	0.3	0.5	0.3	0.2
1984	0.8	0.3	1.0	0.4	0.3	0.4	0.2	0.2
1985	0.9	0.4	0.9	0.3	0.2	0.5	0.2	0.2
1986	1.5	0.4	0.8	0.2	0.2	0.3	0.1	--
1987	1.7	--	0.9	0.2	0.3	0.4	0.1	--

Table 2. Annual commercial and sport catches of coho salmon in millions of fish.

	North America						Asia	
	Calif.-Wash.		British Columbia		SE Alaska	C&W Alaska	Japan	USSR
Year	Comm.	Sport	Comm.	Sport	Comm.	Comm.	High seas	Coastal
means								
1921-50	1.8	--	2.2	--	1.7	0.8	0.3	1.7
1951-70	1.8	0.6	3.4	0.1	1.3	0.6	2.5	1.2
1971	4.1	1.2	4.8	0.4	0.9	0.5	2.8	1.3
1972	2.3	0.9	3.4	0.3	1.5	0.3	3.0	0.5
1973	3.0	0.8	3.5	0.4	0.8	0.6	4.8	0.7
1974	4.1	1.2	3.7	0.8	0.6	0.6	4.6	1.2
1975	2.8	1.0	2.3	0.5	0.4	0.6	3.9	1.2
1976	5.6	1.7	3.7	0.4	0.8	0.6	3.6	1.2
1977	2.2	0.9	3.3	0.7	0.9	0.8	1.8	1.4
1978	2.4	1.0	3.4	1.1	1.7	1.1	3.1	0.7
1979	2.5	0.8	3.6	0.4	1.1	2.0	1.5	1.3
1980	2.3	0.8	3.4	0.6	1.1	2.0	1.9	0.8
		0.7						
1981	2.0	0.7	2.8	0.4	1.4	2.1	1.9	1.1
1982	2.5	0.6	3.2	0.5	2.1	4.0	2.4	1.2
1983	1.4	0.7	4.1	0.4	2.0	1.7	1.4	1.1
1984	1.2	0.4	3.6	0.4	1.9	3.5	1.7	1.5
1985	1.7	0.6	3.0	0.7	2.4	3.1	0.9	1.8
1986	2.3	0.7	4.9	0.6	2.9	2.8	0.5	--
1987	2.5	0.6	3.3	0.7	1.6	1.9	0.5	--

Table 3. Annual commercial catches of sockeye salmon in millions of fish.

	North America				Asia	
Year	Washington Brit. Colum.	Southeast Alaska	Central Alaska	Western Alaska	Japan High seas	USSR Coastal
means						
1921-50	5.5	1.7	6.0	13.8	2.3	7.9
1951-70	6.3	0.9	3.4	8.4	9.8	1.5
1971	9.4	0.6	3.6	9.9	6.6	0.8
1972	4.8	0.9	3.1	2.6	6.9	0.3
1973	10.1	1.0	2.5	0.9	5.9	0.7
1974	9.9	0.7	2.5	1.6	5.4	0.4
1975	4.0	0.2	2.0	5.2	5.2	0.6
1976	6.1	0.6	4.9	6.3	5.8	0.4
1977	8.2	1.0	6.0	5.1	2.8	0.7
1978	8.6	0.7	6.5	10.8	3.2	1.3
1979	7.4	1.0	4.0	23.4	2.9	1.2
1980	3.7	1.1	7.0	25.1	3.2	1.4
1981	9.8	1.1	7.7	27.6	3.1	1.4
1982	13.0	1.5	10.8	16.8	2.5	1.0
1983	5.9	1.6	11.8	39.6	2.5	1.5
1984	6.8	1.2	10.6	26.6	1.9	2.2
1985	15.1	1.8	10.2	26.1	1.3	3.4
1986	12.6	1.4	12.0	18.4	0.9	--
1987	--	1.4	16.3	17.4	0.8	--

Table 4. Annual commercial catches of pink salmon in millions of fish.

	North America				Asia		
	Washington	Southeast	Central	Western	Japan		USSR
Year	Brit. Colum.	Alaska	Alaska	Alaska	High seas	Coastal*	Coastal
means							
1921-50	11.4	28.1	18.3	0.2	4	57	37
1951-70	10.4	11.7	13.5	0.8	37	10	36
1971	11.0	9.3	14.1	0.1	40	12	39
1972	14.2	12.4	3.3	0.2	21	8	14
1973	9.1	6.5	3.3	0.1	36	10	50
1974	7.4	4.9	3.8	1.2	22	8	23
1975	6.0	4.0	8.9	+	34	10	56
1976	10.3	5.3	18.3	1.2	16	6	37
1977	12.7	13.8	14.7	0.1	24	7	74
1978	10.5	21.2	26.5	6.1	10	7	45
1979	16.5	11.0	38.4	0.7	17	6	86
1980	8.2	14.5	43.1	5.7	15	6	53
1981	22.2	19.0	40.5	0.6	18	7	57
1982	2.7	24.2	37.4	3.2	14	6	29
1983	25.9	37.5	22.7	0.1	18	6	69
1984	7.5	24.7	45.8	5.8	14	6	34
1985	24.4	48.9	36.1	+	13	13	61
1986	18.0	43.4	30.5	0.5	7	--	--
1987	--	10.0	35.9	+	7	--	--

*Mostly off USSR coast or in Japan Sea, i.e., USSR origin.

Table 5. Annual commercial catches of chum salmon in millions of fish.

	North America				Asia		
	Washington	Southeast	Central	Western	Japan		USSR
Year	Brit. Colum.	Alaska	Alaska	Alaska	High seas	Coastal	Coastal
means							
1921-50	5.7	4.8	2.5	0.5	4	13*	14
1951-70	2.9	2.4	2.9	0.8	16	4	10
1971	1.5	1.9	4.3	1.4	17	9	4
1972	7.0	2.9	2.7	1.4	22	8	1
1973	6.8	1.8	2.1	2.0	16	11	1
1974	2.7	1.7	0.9	2.2	22	12	2
1975	1.3	0.7	1.3	2.3	19	18	2
1976	2.7	1.0	2.2	2.7	22	11	3
1977	1.6	0.7	3.4	3.2	12	14	4
1978	4.3	0.9	2.6	3.2	7	17	4
1979	1.0	0.9	2.3	2.7	6	26	4
1980	4.3	1.7	3.6	4.3	6	23	4
1981	1.7	0.9	6.8	5.0	6	31	4
1982	4.1	1.4	6.9	2.7	7	27	3
1983	1.6	1.2	5.3	3.7	6	35	5
1984	2.6	4.1	4.4	4.6	6	35	3
1985	6.6	2.4	3.7	3.2	4	48	6
1986	6.7	2.2	5.7	3.1	3	--	--
1987	--	2.6	4.5	3.1	3	--	--

*Mostly off USSR coast.

Table 6. Inriver runs of Columbia River chinook (excluding jacks) in 1,000s.

	Fall stocks				Spring stocks	
	Upriver	Lower river		Bonneville	Upper	Lower
Year	McNary)	Hatchery	Wild	Pool Hatchery	River	River
1971	116	181	108	116	146	95
1972	87	152	79	46	270	65
1973	148	215	49	113	224	84
1974	90	154	27	70	100	107
1975	112	184	37	184	98	68
1976	115	171	15	182	64	81
1977	95	165	30	108	138	92
1978	85	166	18	100	127	107
1979	89	119	33	95	49	69
1980	77	106	39	98	53	73
1981	67	95	25	86	64	93
1982	79	140	13	121	71	107
1983	86	88	17	29	56	94
1984	131	102	13	48	47	116
1985	196	111	13	33	85	84
1986	282	154	24	17	121	91
1987	421	346	37	9	100	131

Source: P.M.F.C.

Table 7. Major fall chinook escapements and the coastal catches for California

	Sacramento an Joaquin Rivers Escapements			Klamath River Catch + escapement			Coastal catch
Year	Adults	Jacks	Total	Adults	Jacks	Total	Comm.+sport
1971	191	48	239				662
1972	100	52	152				692
1973	228	44	272				1015
1974	206	29	235				649
1975	159	36	195				683
1976	169	24	193				621
1977	156	42	198				704
1978	137	20	157				710
1979	168	58	226	50	12	62	849
1980	156	26	182	44	37	81	673
1981	196	66	262	77	28	105	670
1982	174	52	226	65	39	104	909
1983	122	85	207	58	4	62	357
1984	205	64	269	43	9	52	389
1985	304	51	355	59	64	123	521
1986	256	33	289	186	42	228	920
1987	185	79	264	199	24	223	1070

Source: P.M.F.C.

Table 8. Escapements and returns for Nushagak springs and upriver Columbia fall chinook stocks (in 1,000s).

Brood	Nushagak			McNary Fall Chinook			
Year	Run	Escape.	Return	Run	Escape. (Age 3+)	Return (Total)	(Age 3+)
1966	102	40	98	123	51	151	110
1967	165	65	100	164	43	208	137
1968	155	70	110	159	49	151	101
1969	123	35	49	207	55	142	91
1970	144	50	139	177	43	218	175
1971	127	40	175	167	49	150	86
1972	75	25	229	129	38	147	86
1973	72	35	203	212	46	174	118
1974	110	70	124	150	35	211	112
1975	98	70	399	168	30	197	118
1976	168	100	281	214	29	102	52
1977	156	65	473	173	37	119	72
1978	255	130	149	136	27	72	48
1979	262	95	198	136	31	143	100
1980	218	141	107	100	30	219	158
1981	356	150	149	110	21	205	155
1982	356	147	54+	141	31	403	306
1983	313	162		136	49	461+	305+
1984	154	81		229	61	335+	145+
1985	150	72		507	95		
1986	122	43		660	113		
1987	147	84		523	157		

Table 9. McNary fall chinook; escapements, inriver returns (all ages), and smolts released and transported.

Brood Year	McNary fall chinook (in 1,000s): Escapement (age 3 & older)	Return (all ages)	R/E	Priest Rapids smolt releases (in millions): P.R. hatchery source	Other sources	Smolts collected & transported at McNary dam (in millions)
62	36	57	1.6			
63	27	206	7.6			
64	40	93	2.3			
65	41	216	5.2			
66	51	151	3.0			
67	43	208	4.9			
68	49	151	3.1			
69	55	142	2.6			
70	43	218	5.0			
71	49	150	3.1			
72	38	147	3.9	0.7	0.1	--
73	46	174	3.7	2.9	0.0	--
74	35	211	6.1	1.3	0.0	--
75	30	197	6.6	1.9	0.9	--
76	29	102	3.5	1.3	0.0	--
77	37	119	3.2	1.5	0.5	+
78	27	72	2.6	1.2	0.0	0.4
79	31	143	4.6	2.7	0.4	0.7
80	30	219	7.3	4.8	1.7	2.1
81	21	205	9.7	5.5	1.7	1.6
82	31	401	12.9	10.3	6.1	4.2
83	49	461+	9.5+	9.7	11.7	3.9
84	61	335+	5.5+	7.0	0.0	6.4
85	95	--		6.4	0.0	5.8
86	113	--		7.1	0.0	6.7
87	157	--		--	--	--

Table 10. Annual fall chinook salmon counts in thousands, 1964-1987.

Year	McNary Dam		Priest Rapids		Ice Harbor		Volunteers		Hanford Reach*	
	Age 2	Age 3+	Age 2	Age 3+	Age 2	Age 3+	Age 2	Age 3+	Age2	Age 3+
1964	18	40	8	7	2	9			8	24
1965	35	41	13	8	4	8			18	24
1966	24	51	9	10	2	13			12	28
1967	30	43	7	5	5	14			19	24
1968	24	49	6	5	5	19			13	24
1969	24	55	8	5	4	14			13	36
1970	18	43	11	5	1	9		1	6	28
1971	21	49	4	7	2	9		1	15	32
1972	12	38	4	2	2	7		1	6	27
1973	27	46	5	5	2	7		2	20	33
1974	27	35	3	5	1	2		1	24	26
1975	39	30	9	4	1	2			29	23
1976	59	29	5	6	1	1		1	53	22
1977	47	37	3	4	1	1		1	44	32
1978	17	27	2	5	1	1		1	15	21
1979	19	31	3	5	1	1		2	15	23
1980	9	30	2	6	1	1		1	6	22
1981	12	21	2	4	1	1		1	9	15
1982	26	31	4	9	2	2			20	21
1983	25	49	3	8	1	2		1	22	37
1984	49	61	5	8	1	2	1	4	42	47
1985	112	95	9	12	7	2	13	11	83	70
1986	126	113	11	19	3	3	8	11	104	80
1987	47	157	5	35	2	7	2	17	38	98

*McNary—P.R., I.H. and volunteers

Table 11. Chinook salmon redd counts in the Hanford Reach and the McNary and Hanford escapements.

Year	Escapement of age 3+ in 1,000s		D. Watson's aerial redd Counts in 100s	
	McNary	Hanford	Vernita Bar	Other Hanford
64	40	24	6	9
65	41	24	7	11
66	51	28	13	18
67	43	24	13	20
68	49	24	15	21
69	55	36	15	30
70	43	28	15	23
71	49	32	14	22
72	38	27	1	8
73	46	33	9	21
74	35	26	2	5
75	30	23	10	17
76	29	22	6	14
77	37	32	8	24
78	27	21	10	20
79	31	23	10	20
80	30	22	9	6
81	21	15	21	28
82	31	21	22	28
83	49	37	22	31
84	61	47	23	50
85	95	70	24	52
86	113	80	31	52
87	157	98	32	54

Survey method changed in 1981.

Table 12. Estimates of total recruitment for McNary fall chinook adults (age 3+).

Brood Year	Spawning Stock (Escapement)	Inriver Recruitment (Return)	Ocean Harvest Rate	Total Recruitment	R/S
1975	30	118	0.47	224	7.5
1976	29	52	0.53	110	3.8
1977	37	72	0.35	111	3.0
1978	27	48	0.19	60	2.2
1979	31	100	0.29	141	4.5
1980	30	158	0.44	281	9.4
1981	21	155	0.32	228	10.9
1982	31	306	0.31	440	14.2
1983	49	405	0.31	587	12.0

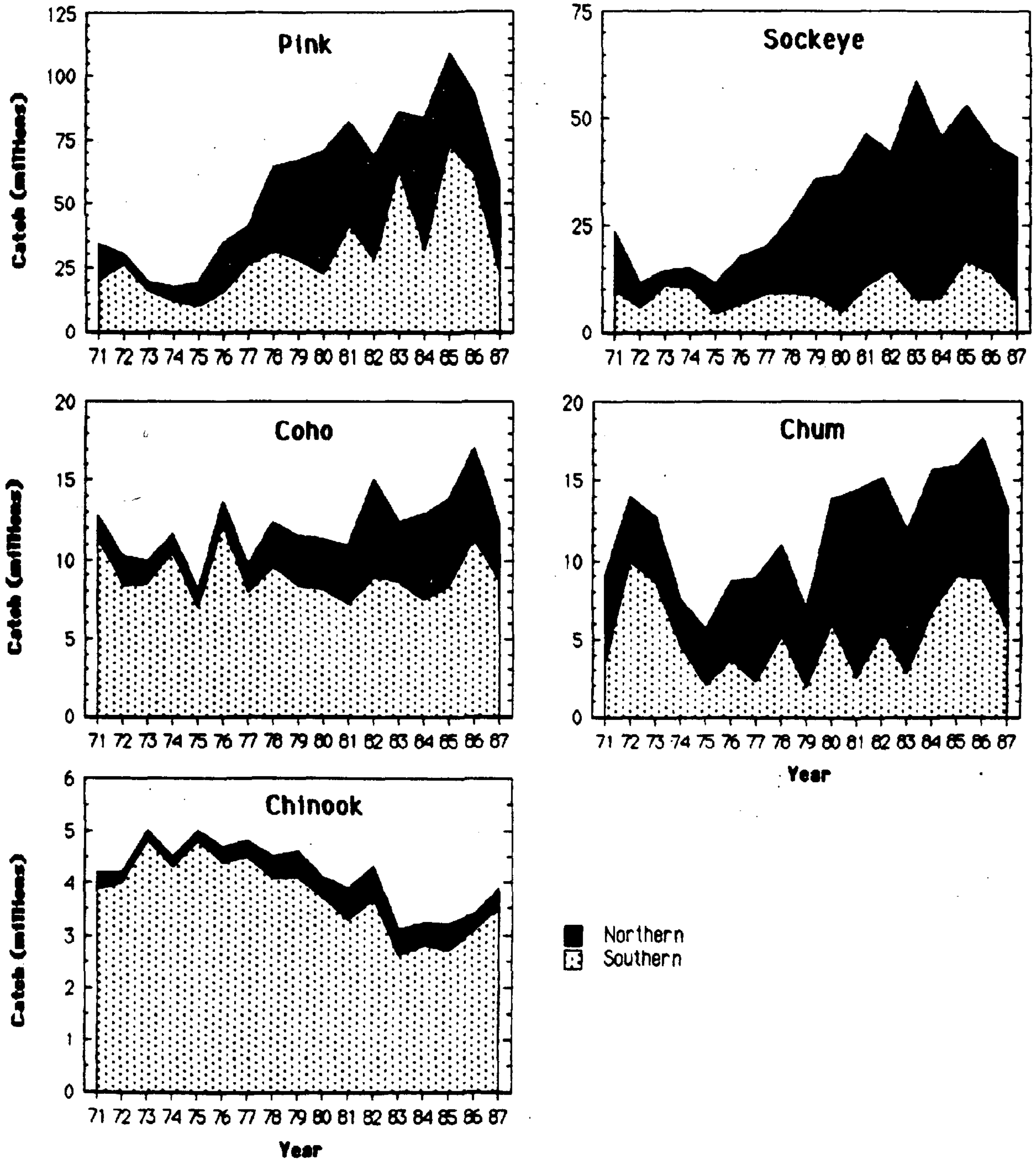


Figure 1. Annual catches of North American salmon by region, 1971-1987.

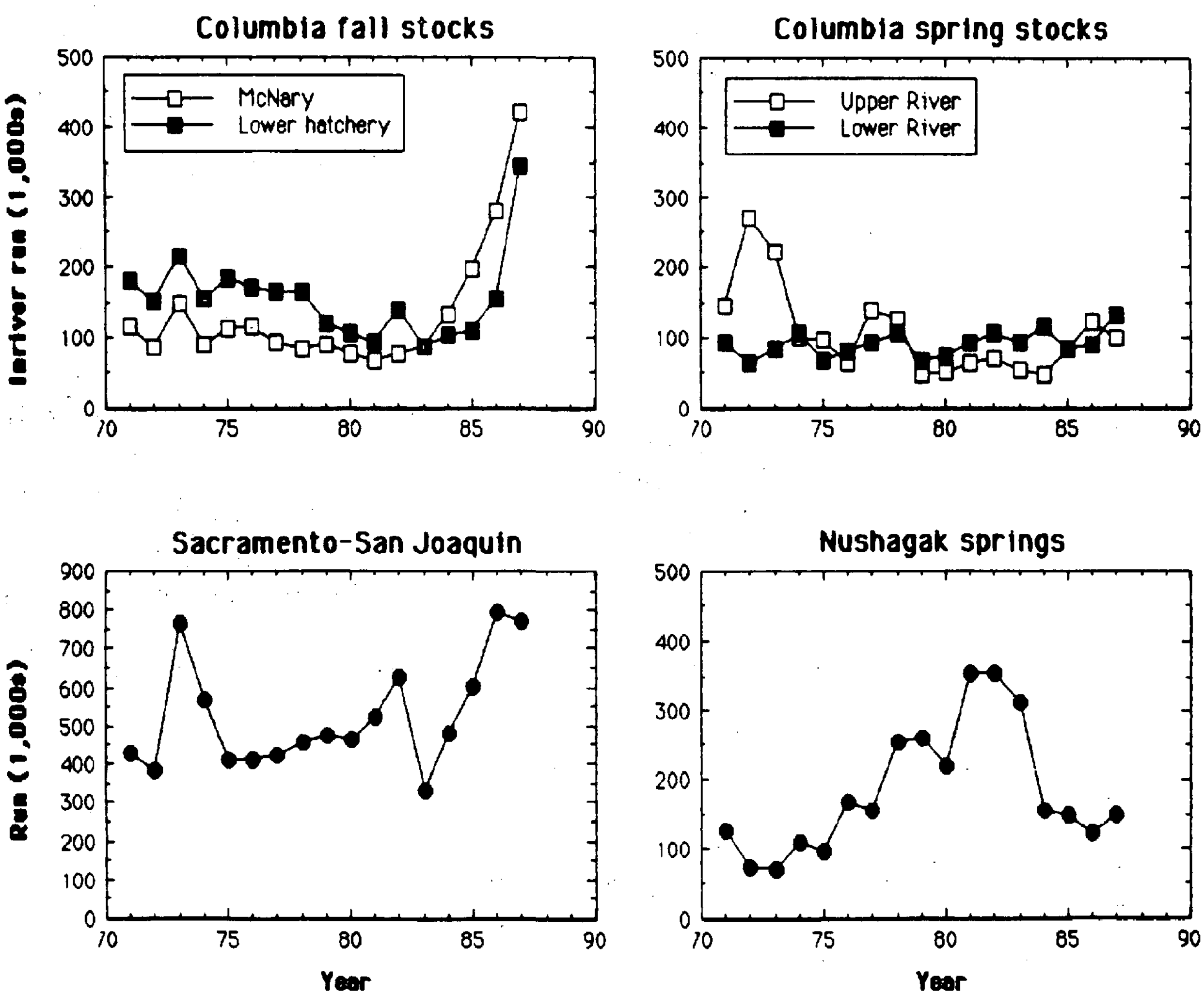


Figure 2. Annual runs of chinook salmon for six North American stock complexes, 1971-1987.

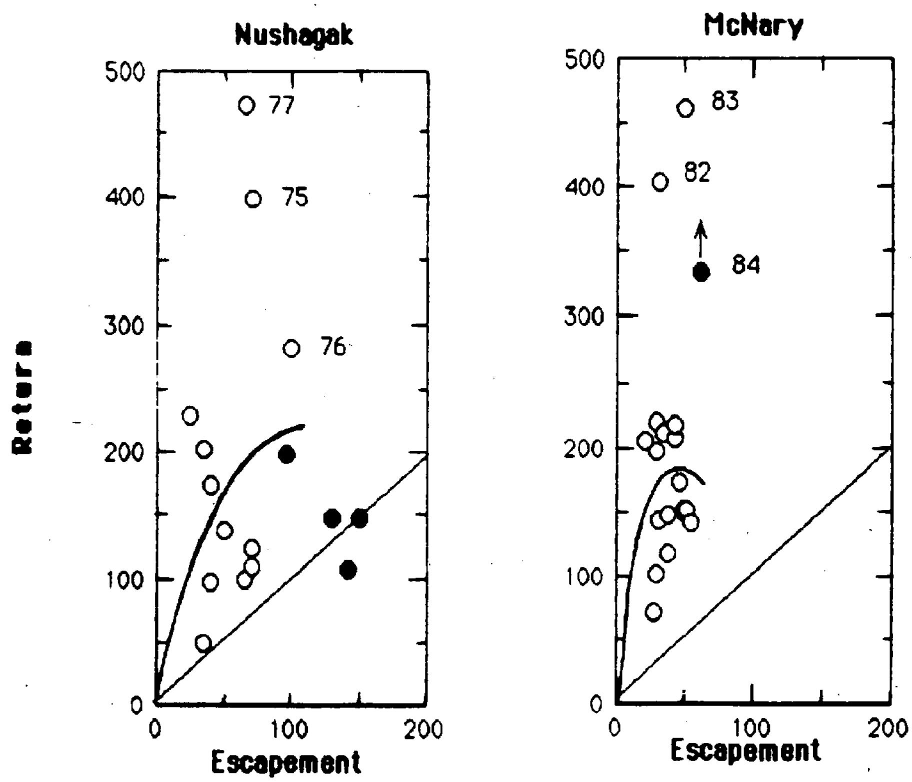


Figure 3. Escapement-return relationships for Nushagak spring chinook salmon and upriver Columbia fall chinooks (McNary). Curve fitted to 1966-1977 brood year returns for the Nushagak with 1978-1981 returns shown by solid points. Curve fitted to 1966-1983 inriver returns to McNary (escapement age 3+, return includes all ages). The 1984 brood year returns for ages 2 and 3 only.

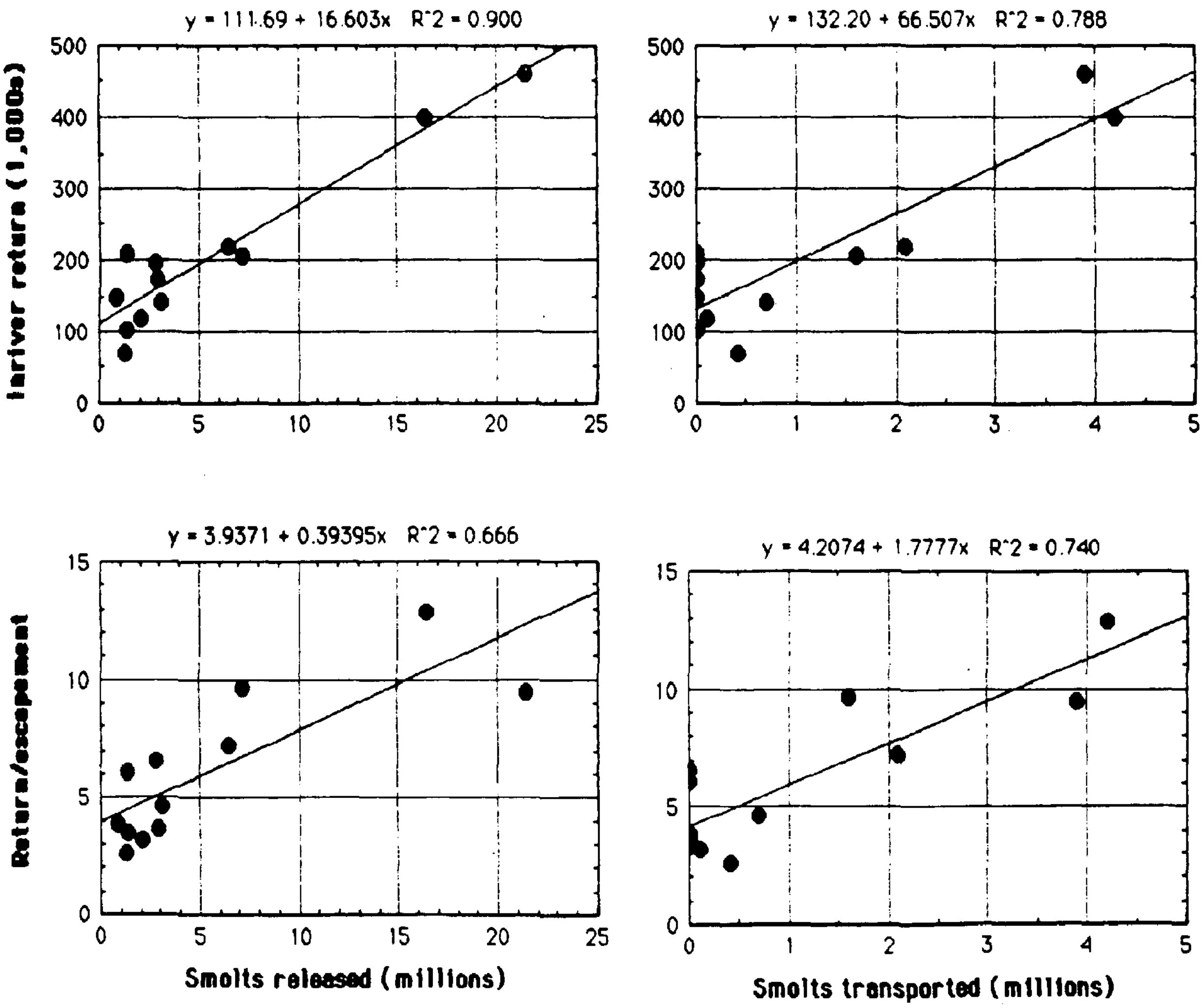


Figure 4. Inriver return and return per escapement regressed on numbers of hatchery smolts released and numbers collected at McNary and transported downstream, 1972-1983 brood years.

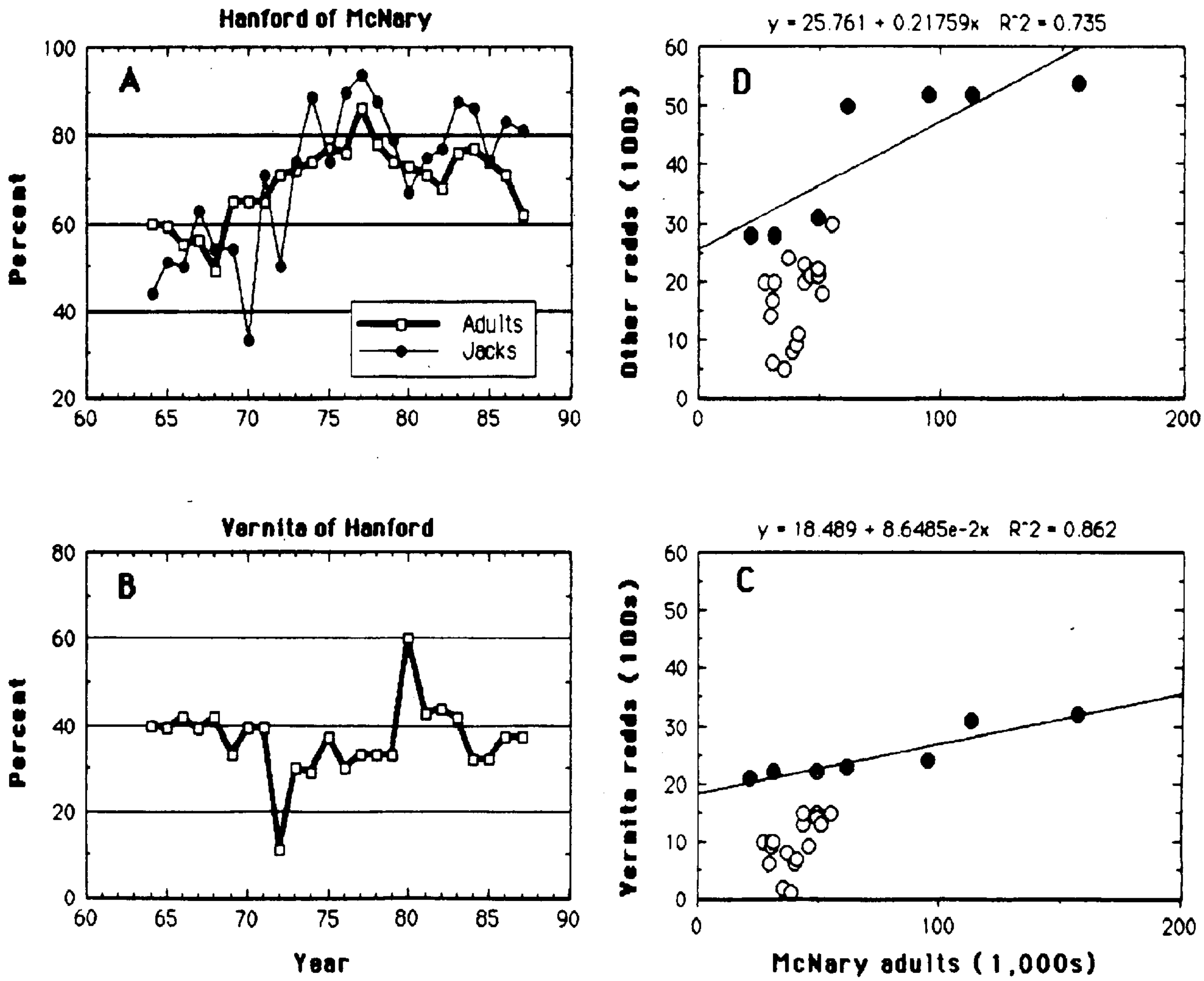


Figure 5. Hanford Reach chinook salmon spawner distribution: (A) percent of McNary escapement estimated to be in the Hanford Reach, 1964- 1987; (B) percent of the number of aerially surveyed redds in Hanford Reach that were counted on Vernita Bar, 1964-1987; (C) number of redds on Vernita Bar regressed on number of adults past McNary, 1981-1987 with observations from earlier years (open circles); (D) number of redds counted in Hanford Reach other than on Vernita Bar regressed on number of adults past McNary, 1981-1987 with observations from earlier years (open circles).

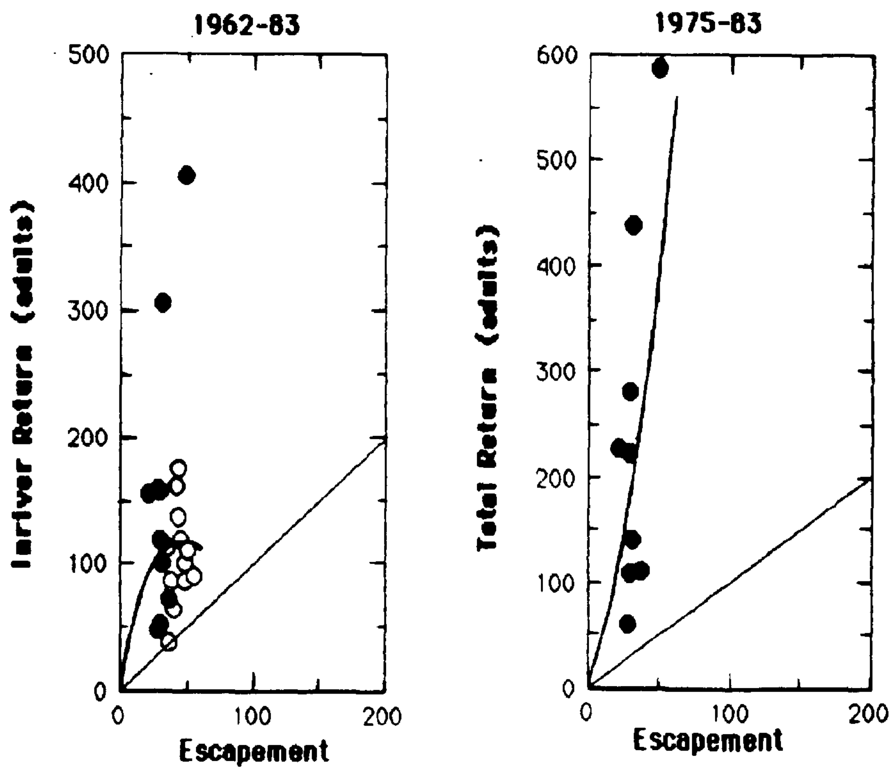


Figure 6. Escapement-return relationships for McNary fall chinook salmon (excluding jacks); inriver returns (left) and total returns, including ocean catches (right).

DOE BP-35885-1
December 1988
3C

NOAA COASTAL SERVICES CENTER LIBRARY
3 6668 00002 5553